Author Affiliation:
Department of Civil Engineering, Akwa Ibom State University, Ikot Akpaden, Akwa Ibom State, Nigeria

*Corresponding author:
Department of Civil Engineering, Akwa Ibom State University, Ikot Akpaden, Akwa Ibom State, Nigeria
Email: udemeudokpoh@aksu.edu.ng

DISCOVERY
SCIENTIFIC SOCIETY

Environmental impact assessment of groundwater pollution within cemetery surroundings

Christopher Brownson Afangideh, Udeme Udeme Udokpoh*

ABSTRACT

The purpose of this study was to assess if human corpses, embalming fluid, and casket materials affect the quality of groundwater in an active urban cemetery in Uyo, Akwa Ibom State, Nigeria. Water samples were collected at predetermined radial distances from the cemetery and subjected to a variety of analyses to determine heavy metals and physicochemical elements using standard procedures. The concentrations of parameters were higher in groundwater samples collected up to 500 m from the cemetery's perimeter. When the results of water quality parameters were compared to those of the WHO, it was observed that there was evidence of attenuation with distance. Pollutant concentrations were found to be higher in soil samples taken both within and outside the cemetery. However, high pH, salinity, TDS, BOD, and heavy metals concentrations in groundwater samples indicate that increased interment density over time poses a substantial danger to groundwater quality.

Keywords: cemetery; contamination; decomposition; groundwater; heavy metals; water quality

1. INTRODUCTION

In Nigeria, groundwater is a significant freshwater resource both in urban and rural areas (Adekunle et al., 2007). It is a significant resource that is often evaluated for use in industrial, commercial, agricultural, and domestic applications (most importantly, for drinking). Land use and groundwater quality are linked, according to Ikem et al. (2002) and Majolagbe et al. (2011). Groundwater pollution is caused by a variety of anthropogenic activities. Leachate from these activities is the source of groundwater pollution. Municipal refuse dumpsites, liquid waste from industrial discharge, domestic waste, agricultural chemical applications, cemetery decomposition, oil spillage, pipeline vandalism, and geological formations are all sources of groundwater pollution (Majolagbe et al., 2011). Groundwater will be polluted owing to the presence of microorganisms, viruses (Neckel et al., 2016), heavy metals, and other hazardous compounds as a result of these

activities (Spongberg & Becks, 2000; Jonker and Olivier, 2012). Polluting groundwater threatens many valuable water resources (Udokpoh et al., 2021). Agriculture, industries and landfill activities are often regarded as major anthropogenic sources of environmental pollution. Cemeteries have received little attention as potential sources of pollution. Most existing cemeteries were established without regard for possible threats to the local environment or community. Cemeteries in Nigeria are frequently built near communities due to religious and cultural reasons or a lack of land availability in populated areas. The same can be said about Brazil, South Africa, and most developing countries (Idehen, 2020; Fineza et al., 2014; Jonker and Olivier, 2012). Several have also been sited without proper geological and hydrological assessments, thereby posing environmental and public health issues (Üçisik & Rushbrook, 1998). Cemeteries are one of the most significant anthropogenic causes of groundwater pollution in urban areas and beyond (Żychowski, 2012; Silva et al., 2011). According to the findings of completed studies, cemeteries may be compared to a specific type of public solid waste dump site. As a result, cemeteries can be a source of groundwater contamination and a possible threat to human health (Ahmadzadeh and Dolatabadi, 2018; Fiedler et al., 2012).

During the breakdown process of a typical adult human corpse, 1 kilogram of body weight releases about 0.4-0.6 litres of leachate with a density of 1.23 gcm^{-3} (Silva, 1995). Pathogenic bacteria and viruses contained in the leachate can pollute groundwater and cause disease when utilised for drinking (Żychowski and Bryndal, 2015). It is composed of 60 percent water, 30 percent salts in the form of ions comprising nitrogen, phosphorus, Cl, HCO_3^-, Ca^{2+}, Na^+, metal compounds (e.g., Titanium, Chromium, Cadmium, Lead, Iron, Manganese, Nickel), and 10 percent organic components. (Żychowski, 2008; Matos, 2001; Silva, 1998). High conductivity, pH, and biochemical oxygen demand (BOD) values, as well as the unique fishy odor, distinguish the leachate (Matos, 2001). The pollutants derived from the body may include chemical compounds used in chemotherapy and embalming procedures (e.g., formaldehyde, arsenic and methanol). Microorganisms in these leachates may contaminate both surface water and groundwater courses. Bacteria, viruses, intestinal fungus, and protozoa are the most common microorganisms. (Trick et al., 2001). Bacteria such as Enterobacter, Streptococcus faecalis, Salmonella typhi, Citrobacter, Escherichia coli, Clostridium perfringens, Clostridium welchii, and Klebsiella are released from the corpses of healthy human or animal. Also human-hosted viruses such as enterovirus are released from the body. (Castro, 2008; Dent et al., 2004; Matos, 2001). Most environmental contamination is caused by E. coli (Gleeson and Gray, 2002), Pseudomonas aeruginosa (Dent, 1998; Dent, 2004), and Clostridium perfringens (Martins et al., 1991) which are pathogenic intestinal bacteria. Most of these bacteria expedite organic matter breakdown and are not harmful (ychowski and Bryndal, 2015). Many pathogens die gradually after the host body dies when environmental conditions are unfavorable because they cannot survive long outside of the host body. Among them are Bacillus anthracis, Mycobacterium TB, Yersinia pestis, Salmonella typhi, Vibrio cholerae, HIV (human immunodeficiency virus), hepatitis virus, and variola virus (Morgan, 2004; Dent, 2004; Matos, 2001; De Ville de Goyet, 2000; Cook, 1999; Trick et al., 1999). Some microorganisms, such as variola virus, B. anthracis, and Clostridium spp., are long-lived and may persist in soil profiles or groundwater for extended periods of time under certain environmental circumstances (Haagsma, 1991; West et al., 1998). The duration of survival varies (Creely, 2004). Reduced temperature, high moisture content in soil associated with lower microbial activity, higher organic matter content, and more alkaline environment are the conditions that increase the survival duration of these microorganisms, particularly endospores (Pacheco, 2000). According to Creely (2004), diseases and saprophytes have a maximum life duration of 2 to 3 years under the earth. This time is shorter in the case of V. cholera, they last around 4 weeks. But, some microbes, such as E. coli, may persist for up to 5 years and move into groundwater during this period (Romero, 1970; Rudolfs et al., 1950). The migration process typically takes 1 to 4 weeks (Pacheco, 1986). According to Dent (2004), this process might take up to 100 days in Australia. According to some researchers, this interval might be prolonged to 6 to 8 months (Silva, 1994). Other factors that impact the leaching and disintegration of these contaminants into groundwater include soil type, pH, rainfall intensity, and temperature (Van Allemann et al., 2018).

Many researchers believe that all cemeteries are potential environmental concerns (Rodrigues & Pacheco, 2003; Dent, 2004). Cemeteries, on the other hand, are not only the final resting place for bodies, but also for coffins utilised for the interment of corpses, makeup (e.g., cosmetics, pigments, and chemical compounds), and various other items such as paints, fillings, varnishes, metal hardware elements, cardiac pacemakers, iron nails, etc (Fiedler et al., 2012; Silva and Filho, 2011). Indeed, recent investigations have discovered that the most pollution in cemeteries is caused by minerals released by burial loads (Borstel, 2000). The minerals used in coffin production may corrode or decompose, unleashing hazardous poisonous substances (Spongberg and Becks, 2000). These substances may be carried from the graves by seepage and permeate into the underlying soils. They may then seep into groundwater, posing a health danger to individuals in communities near the cemetery (Canninga and Szmigina, 2010; Williams et al., 2009; Kim et al., 2008; Dent and Knight, 1995). Toxic chemicals that may be released into groundwater are from substances used as embalming fluid, as well as paints, sealants, preservatives, metal handles, and embellishments used on wooden coffins. Wood preservatives and paints used in coffin construction contain minerals such as copper naphthalene and ammoniac or

chromated copper arsenate (CCA). (Spongberg and Becks, 2000; Atlas and Bartha, 1987). Aside from CCA, other wood treatments include ammonium copper quaternary (ACQ) and copper boron azole (CBA) (Chou et al., 2007). Prior to the 1940s, lead compounds were widely used as colourants in paints. (Marqardt et al., 1996). Manganese, nickel, copper, vanadium, and some toxic metals, were found in antique paint samples (Mielke et al., 2001). Many paints still include mercury, lead, chromium, and cadmium. (Gondal et al., 2011; Huang et al., 2010; Katz and Salem, 2005). Arsenic is used as a colour and a corrosion inhibitor, whereas barium is used as a colour, a wood preservative, and an anti-fouling element (Jonker and Olivier, 2012). Metal is also used for the handles and other ornamentation on the exterior of a casket. Fasteners and coffin embellishments contain minerals such as silver, copper alloys, bronze, and zinc. These artifacts are typically spray painted, vacmetalised, electroformed, or a mix of these treatments to increase their visual appeal. Although wood has traditionally been used in the construction of coffins in Nigeria and other developing countries, the cost of wood is rising. However, less expensive materials such as cardboard, plywood, MDF boards, chipboard, or pressboard are being utilised as substitutes (Baur, 2002). These plywood materials may contain preservatives such as chromium and copper, which are regulated by the Hazard Communication Standards. Another recent new advancement in the field of coffin construction is the use of light-weight titanium (Keijzer and Kok, 2011).

Cemeteries in Nigeria are usually positioned near to communities, within the radius of influence of groundwater sources. Cemeteries were never thought to have a significant potential contaminating effect on the environment. As a backdrop, the potential hazard of cemeteries having a negative influence on ground and surface water in Nigeria has gotten little attention. With just a small amount of published evidence accessible, the present degree of understanding of the pollution loads from cemeteries is insufficient. Turajo et al. (2019), one of the few studies available, examine whether burial practices influence groundwater in the vicinity of an active municipal cemetery in the Gwange section of the Maiduguri metropolis, Borno State, Nigeria. Groundwater quality was also measured from boreholes situated at varied radial distances from the cemetery. The results were compared to those of the WHO and revealed evidence of reduction with distance. Alagbe et al. (2020) also investigated the possible threats from subterranean water sources near burial sites in order to offer preliminary data on the influence of such toxins on water quality and the ecosystem. Samples were gathered from 9 places (7 bore hole outlets and 2 dug wells) within 500 metres of the Ayobo cemetery in Lagos, Nigeria, and analysed for physicochemical parameters using conventional methods. Among the metrics examined, samples displayed high salinity (5.5 ± 1.9), somewhat acidic pH values (5.23 ± 0.94), and considerably higher lead concentrations (0.63 0.27). To date, no similar studies have been undertaken in Akwa Ibom State, a south-south geopolitical region of Nigeria with a shallow groundwater table, loose soil formation, and year-round rainfall.

Nonetheless, research on cemeteries as a possible source of groundwater pollution has focused on pollutants emitted by the corpses. Casket materials, embalming fluid, cosmetics, etc., as potential sources of leachate to groundwater have received little attention. However, it is against these shortcomings that the authors seek to investigate the degree of groundwater and soil contamination caused by embalming fluid and casket materials in the cemetery and its surrounding. To accomplish this, water and soil samples were subjected to various analyses in order to determine the heavy metal and physicochemical elements. These components in water and soil samples from the cemetery and its surroundings were compared to those found elsewhere (location where there is no cemetery).

2. METHODOLOGY

Sampling design of the study

In order to acquire the necessary information, we performed formal and informal interviews with relevant individuals (cemetery undertakers and cemetery workers), as well as fieldwork and observations. In addition, we collected field samples and analysed soil and water in the laboratory.

Study area description

Uyo is the capital of Akwa Ibom State, which is located in Nigeria's south-south geopolitical area (Figure 1). It is situated on a huge underlain conglomerate sedimentary layer at an elevation of 45 meters above sea level (Udo and Mode, 2013). The climate is tropical rainforest with two distinct seasons: a short dry season from December to February with daytime temperatures ranging from 34 to 38 degrees Celsius and cooler nighttime temperatures ranging from 23 to 25 degrees Celsius. This is followed by a long rainy season from March to November, with daily minimum temperatures of 23 degrees Celsius and high temperatures of 29 degrees Celsius, relative humidity ranging from 60 to 100 percent, and annual rainfall ranging from 2000 to 3000 mm. (Etim et al., 2009). However, humidity is normally low throughout the dry season and rises during the wet season when temperatures decrease (Mala et al. 2012). The maximum yearly precipitation rate of 60 to 70% is usually seen between June and July. Because to its

location just north of the Equator and inside the humid tropics, as well as its proximity to the sea, the area is frequently humid, as evidenced by relative humidity levels of 60 and 100 percent in the dry and wet seasons, respectively. Naturally, the maximum humidity levels are recorded in July, while the lowest levels are recorded in January. From March through November, the thick cloud cumulonimbus type is most common. The area's potential evapotranspiration is significant, with an estimated annual average of 1500 to 1800mm. Uyo is entirely located in the tropical forest zone, with mangrove forest vegetation.
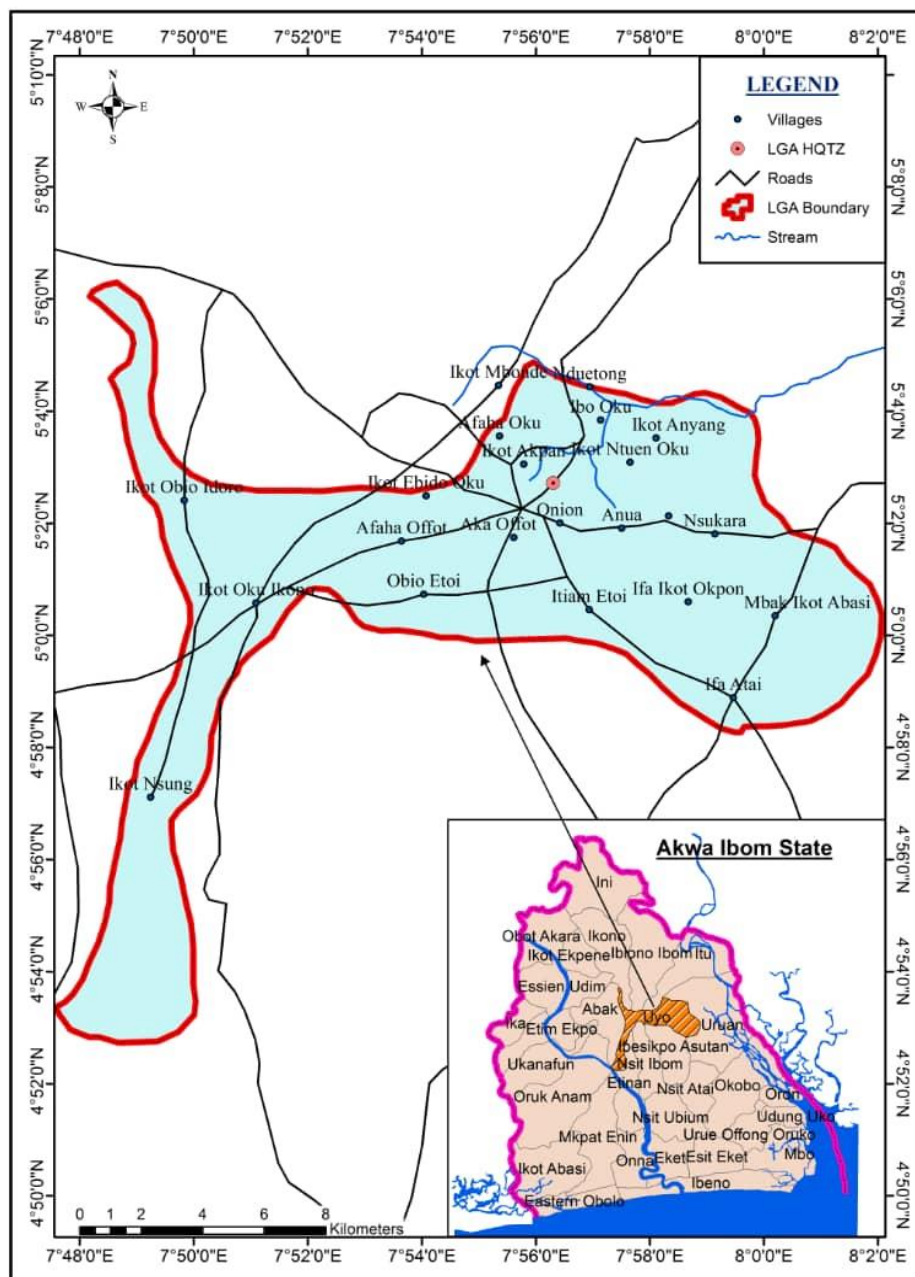
Figure 1: Map of study area

The Use Offot cemetery is a public cemetery in the Offot district of Uyo. The cemetery has a total surface area of 90,000 square metres (300m x 300m), approximately 9 hectares in size, and is flanked by residential buildings. Because the government prohibited the burying of bodies in residential buildings inside Uyo municipality, the cemetery received a lot of patronage from the inhabitants, and it had reached its full capacity years ago. Despite this, people continue to bury their loved ones at this cemetery.

Sample collection and analysis
Soil samples were taken at five places throughout the cemetery at different depths (1 to 2m and 2 to 3m) using a hand driven auger of 150 mm diameter. At the site where water samples were tapped 50m to 500m downstream of the cemetery, soil samples were

gathered at the same depths above. Three of the samples (holes 1, 2, and 3) were gathered from existing excavated graves in the cemetery downstream, whereas the other two (pits 4 and 5) were collected near excavated graves in the cemetery upstream. During a severe rainfall, surface runoff defined the upstream and downstream of the cemetery. All safety procedures and practices for collecting possibly contaminated soil samples in historical cemeteries were followed, including the use of a facemask, coverall, latex gloves and booties. Water samples were taken at distances of 50, 100, 200, 400, and 500 metres from the cemetery. One kilogram of soil sample was taken from all of the sampling points at each spot and depth and placed in polyethylene bags. Water samples of 500 millilitres (0.5 L) were collected from each borehole and preserved in plastic bottles. Prior to collection, all bottles were washed 2 to 3 times in the field using representative groundwater samples as part of quality control methods. After 5 to 10 minutes of pumping, the water sample is collected from the borehole to check that the samples were typical of the aquifer. Each bottle was labeled with the sampling site, and all of the samples were stored in a refrigerator for 24 hours before being analysed. For simple identification, all of the samples were labeled with the date, time, sample ID, and sample depth. The samples were transferred to a certified laboratory run by the Akwa Ibom State Ministry of Science and Technology for analysis. The water and disturbed soil samples were subjected to a variety of laboratory tests.

The water samples were analyzed using laboratory procedures similar to those used by Alagbe et al., (2020) and Turajo et al., (2019). All of the samples were subjected to various physicochemical and heavy metal analyses. The parameters assessed were confined to those having a high tendency of influencing drinking water quality, as recommended by the World Health Organisation and the Environmental Protection Agency (EPA). Using the pH meter model HACH SENSION 3 and the turbid meter model 2100P TURBIDIMETER, the pH and turbidity of the samples were determined. The pH meter was preheated for around 15 to 20 minutes before use. A conductivity meter model HACH SENSION 5 was used to determine the total dissolve solid. A spectrophotometer model DR 2010 HACHSENSONS was used to determine the heavy metal parameters. In the statistical study, Excel was utilised to determine the Coefficient of Variation (CV), Correlation Coefficient and ANOVA. The findings of the various indicators were compared to WHO (2011) drinking water quality recommendations.

3. RESULTS AND DISCUSSION

3.1. Results

Laboratory mean results for physiochemical and heavy metal analyses of borehole water samples obtained at varied distances from the cemetery are presented in Table 1 and Figure 2. Table 2 and Figure 3 show the results of the same studies for soil samples collected at various depths upstream and downstream of the burial environment. Table 3 and Figure 4 shows the same analytical results for soil samples obtained up to 500 meters distant from the cemetery. Tables 5-7 show the findings of a statistical analysis conducted to evaluate the link between water quality parameters and the level of pollution in the study region, as well as the variance in parameters based on distance from the cemetery and depth.
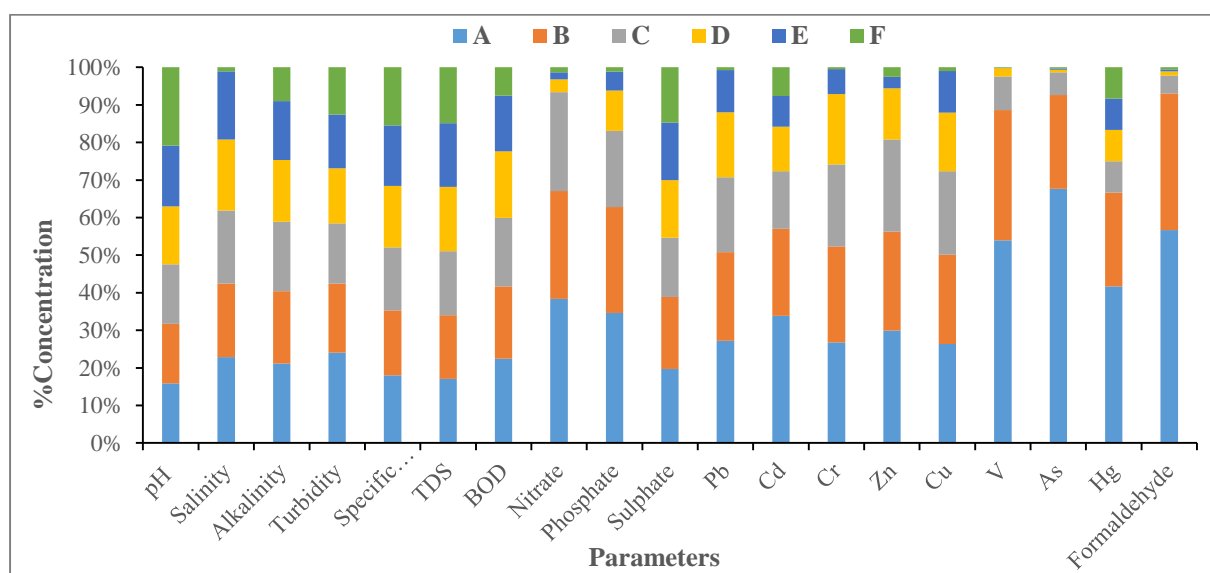
Figure 2: Comparison of water quality parameters
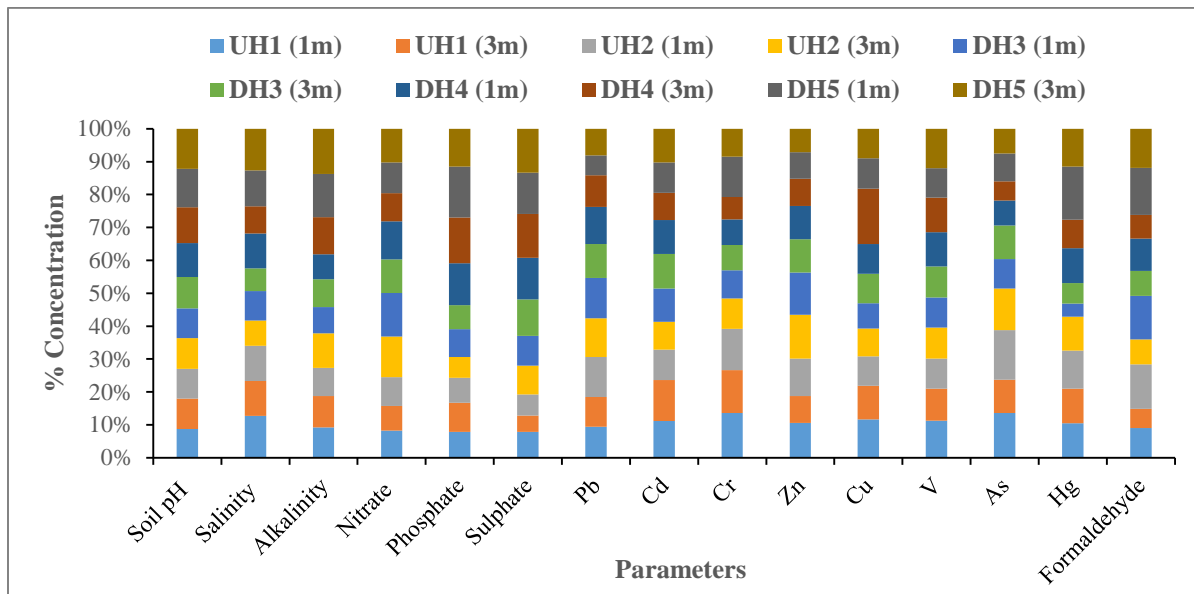
Figure 3: Comparison of soil quality parameters within the cemetery
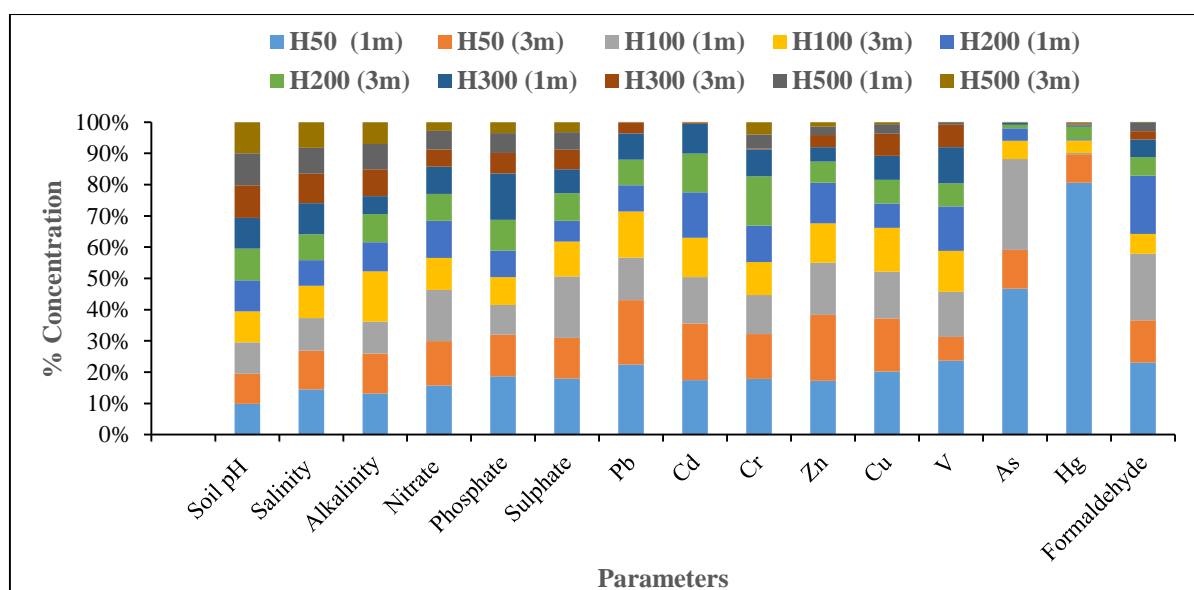
Figure 4: Comparison of soil quality parameters at measured distances from the cemetery

Table 1: Boreholes water quality at measured distances away from the cemetery

Parameters	Samples					
	A(50m)	B(100m)	C(200m)	D(300m)	E(500m)	F(2km)
Ph	5.13	5.10	5.09	4.98	5.22	6.70
Salinity	10.70	9.22	9.10	8.87	8.50	0.49
Alkalinity	10.12	9.22	8.87	7.87	7.50	4.30
Turbidity (NTU)	1.70	1.30	1.13	1.03	1.01	0.89
SG	1.083	1.042	1.010	0.982	0.971	0.931
TDS	7.07	7.02	7.05	7.08	7.01	6.14
BOD	3.83	3.30	3.12	3.03	2.53	1.29
Nitrate	1.607	1.203	1.101	0.142	0.078	0.056
Phosphate	0.984	0.801	0.576	0.307	0.142	0.033
Sulphate	1.358	1.320	1.089	1.055	1.055	1.013

Pb	1.505	1.305	1.101	0.956	0.623	0.040
Cd	0.893	0.612	0.406	0.312	0.216	0.201
Cr	0.917	0.876	0.745	0.643	0.228	0.016
Zn	3.760	3.313	3.080	1.706	0.387	0.319
Cu	2.098	1.890	1.785	1.245	0.876	0.081
V	0.507	0.325	0.084	0.021	<0.001	<0.001
As	0.203	0.075	0.018	0.002	<0.001	<0.001
Hg	0.005	0.003	0.001	<0.001	<0.001	<0.001
Formaldehyde	0.106	0.068	0.009	0.002	<0.001	<0.001

A, B, C, D, E and F are borehole water samples approximately 50m, 100m, 200m, 300m, 500m and 2km away from the cemetery perimeter. All parameters are in mg/l except where it is stated.

Table 2: Soil quality at upstream and downstream within the cemetery

PARAMETERS	UH_1 (1m)	UH_1 (3m)	UH_2 (1m)	UH_2 (3m)	DH_3 (1m)	DH_3 (3m)	DH_4 (1m)	DH_4 (3m)	DH_5 (1m)	DH_5 (3m)
Soil Ph	4.91	5.27	5.07	5.29	5.1	5.38	5.87	6.12	6.6	6.89
Salinity	22.3	18.5	18.7	13.6	15.6	12.1	18.5	14.6	19.1	22.1
Alkalinity	15.36	15.86	14.23	17.65	13.27	14.1	12.61	18.81	21.85	22.9
Nitrate	10.43	9.37	11.06	15.52	16.58	12.83	14.67	10.68	11.8	12.86
Phosphate	6.42	7.21	6.13	5.16	6.83	5.96	10.34	11.32	12.61	9.34
Sulphate	7.73	4.86	6.3	8.54	8.92	10.83	12.46	13.03	12.34	13.09
Pb	0.932	0.902	1.201	1.168	1.224	1.021	1.124	0.951	0.601	0.801
Cd	1.089	1.218	0.906	0.829	0.991	1.023	1.013	0.811	0.902	1.001
Cr	1.465	1.398	1.351	0.989	0.918	0.832	0.833	0.73	1.323	0.907
Zn	4.918	3.812	5.289	6.157	5.965	4.743	4.665	3.875	3.718	3.325
Cu	2.718	2.357	2.084	1.97	1.789	2.085	2.085	3.925	2.143	2.082
V	1.31	1.135	1.071	1.101	1.061	1.106	1.21	1.221	1.041	1.401
As	1.621	1.215	1.802	1.501	1.071	1.22	0.91	0.701	1.002	0.901
Hg	0.521	0.525	0.581	0.511	0.201	0.311	0.531	0.431	0.803	0.576
Formaldehyde	3.856	2.498	5.789	3.237	5.689	3.22	4.209	3.098	6.103	5.102

UH_1 and UH_2 are soil samples taken from upstream pit 1 and 2 respectively within the cemetery; DH_3, DH_4, and DH_5 are soil samples taken from downstream pit 3, 4 and 5 within the cemetery. All parameters are in mg/l except where it is stated.

Table 3: Soil quality at measured distances away from the cemetery

PARAMETERS	H_{50} (1m)	H_{50} (3m)	H_{100} (1m)	H_{100} (3m)	H_{200} (1m)	H_{200} (3m)	H_{300} (1m)	H_{300} (3m)	H_{500} (1m)	H_{500} (3m)
Soil Ph	5.16	5.02	5.27	5.23	5.17	5.3	5.18	5.44	5.4	5.19
Salinity	12.4	10.7	8.9	8.9	7.1	7.1	8.5	8.1	7.1	7.1
Alkalinity	5.96	5.86	4.63	7.34	4.24	4.12	2.62	3.91	3.65	3.2
Nitrate	4.78	4.35	5.02	3.12	3.62	2.63	2.67	1.68	1.8	0.86
Phosphate	1.82	1.29	0.93	0.86	0.83	0.96	1.44	0.64	0.62	0.34
Sulphate	5.73	4.16	6.3	3.56	2.12	2.83	2.45	2.01	1.8	1.01
Pb	0.332	0.303	0.201	0.218	0.124	0.121	0.124	0.051	0.001	<0.001
Cd	0.592	0.618	0.503	0.429	0.492	0.423	0.323	0.015	0.002	<0.001
Cr	0.489	0.392	0.341	0.289	0.318	0.432	0.233	0.01	0.123	0.107
Zn	3.918	4.82	3.819	2.857	2.965	1.543	1.065	0.875	0.618	0.325
Cu	2.818	2.387	2.084	1.97	1.089	1.057	1.075	0.995	0.43	0.082

V	0.328	0.105	0.201	0.181	0.198	0.101	0.161	0.1	0.01	<0.001
As	0.811	0.215	0.506	0.1	0.07	0.02	0.01	<0.001	0.002	<0.001
Hg	0.221	0.025	<0.001	0.011	<0.001	0.011	<0.001	<0.001	0.001	<0.001
Formaldehyde	0.856	0.498	0.789	0.237	0.689	0.22	0.209	0.098	0.105	0.002

H_{50}, H_{100}, H_{200}, H_{300} and H_{500} are soil samples taken at 50m, 100m, 200m, 300m and 500m away from the cemetery perimeter. All parameters are in mg/l except where it is stated.

The pH values of borehole water samples in the study area varied from 4.98 to 6.70, with water sampled two kilometres (2km) distant from the cemetery having a pH value more than 6.5, which is within the WHO-recommended limit. The pH levels of water samples obtained up to 500 metres (m) away from the cemetery environment, on the other hand, did not meet the WHO's permissible limit in drinking water. Borehole water samples obtained in all six (6) positions had mean salinity values ranging from 0.49 to 10.70, with the sample fetched approximately fifty metres (50m) away from the cemetery recording the highest salinity value of 10.70, and salinity values decreasing linearly with increasing distance from the cemetery. In the same line, increased alkalinity levels were found in water samples taken near the cemetery. The values varied from 10.12 to 4.30. The turbidity level of the borehole water samples ranged from 0.89 NTU to 1.70 NTU and was less than 5.0 NTU, which is the permissible limit in drinking water. The specific gravity readings range from 0.931 to 1.083 in all borehole water samples. Specific gravity values greater than 1.0 were found in samples collected at approximately 50m, 100m, and 200m. The total dissolved solids levels in all of the water samples ranged from 6.14 to 7.07, all of which were higher than the WHO limit of 5.0. Even a comparable sample fetch at approximately 2km far beyond cemetery grounds revealed a result greater than the allowable threshold in portable water. Except for water samples obtained 500m and 2000m distant from the cemetery, almost all borehole water samples had a BOD value more than 3.0 mg/L, the permissible limit for drinking water. These samples had BOD values of 2.53 mg/L and 1.29 mg/L, respectively. Nitrate levels in all water samples were below the allowed limit of 50 mg/L in portable water. The values were found to grow linearly as the distance to the cemetery decreased. Phosphate levels in all water samples varied from 0.033 mg/L to 1.607 mg/L, well below the acceptable limit of 3.5mg/L. Sulphate levels in all of the water samples taken in the study area ranged from 1.013 mg/L to 1.358 mg/L.

The heavy metal analysis results reveal that there is a high quantity of lead in all of the water samples, ranging from 0.040 mg/L to 1.505 mg/L, with all of the samples having levels that above the WHO acceptable limit of 0.01 mg/L Pb in drinking water. Cadmium concentrations in all of the drinking water samples ranged from 0.201 mg/L to 0.893 mg/L, with all of the samples above the WHO-recommended limit of 0.003 mg/L. Except for the reference sample, which had a value of 0.016 mg/L, chromium contents in all borehole water samples varied from 0.016 mg/L to 1.348 mg/L and were not within the WHO acceptable limit of 0.01 mg/L. Zinc contents varied from 0.319 mg/L to 3.760 mg/L in all borehole water samples. Samples A, B, and C exceeded the WHO acceptable limit of 3.0mg/L, whereas samples D, E, and F were within the permitted range. Copper levels in water samples A–D were significantly higher than the permitted limit in portable water, indicating a significant level of contamination. Samples E and F had lower concentration levels than the other samples, but they were still within the permitted range. Vanadium concentrations in borehole water are greater in samples A, B, C, and D, according to test data. The values varied from 0.021 mg/L to 0.507 mg/L, which is much higher than the WHO drinking water guidelines of 0.001 or zero. The analytical findings also show that the concentrations of arsenic, mercury, and formaldehyde in borehole water from samples A, B, and C in the study region are greater than the allowable limit. For the three parameters, the values from water samples E and F were generally satisfactory. Young et al. (1999) discovered significant levels of formaldehyde (8.6 mg/l) at the recent burial site in Northwood Cemetery in West London.

The results of the laboratory analyses for soil quality demonstrate that these parameters are present in high concentrations and varied proportions in soil samples obtained within the cemetery. Soil samples taken from existing graves had a greater concentration of these parameters than samples taken near an already dug grave. In contrast, the levels of pollutants in certain samples taken at 1m deep were greater than those collected at 3m depth. In several samples, the opposite tendency was seen. This might be attributed to pollutants leaching into the underlying soil formation during infiltration, which is enhanced by soil type and precipitation. Similarly, samples collected downstream within the cemetery exhibited a greater concentration of pollutants than ones collected upstream. The concentration of contaminants in soil samples collected at various distances from the cemetery was shown to decrease linearly with increasing distance away from the cemetery. This pattern was also observed in water samples collected around the same location. This is consistent with the findings of (Żychowski, 2012), who discovered that high concentrations of pollutants decreased rapidly as one moved away from the burial sites. Gray et al. (1974) equally observed a decrease in pollution levels as one moved away from cemeteries.

Table 4: Correlation coefficients of borehole water quality parameters

	pH	Sal	Alk	Turb	SG	TDS	BOD	Ni	Ph	Sul	Pb	Cd	Cr	Zn	Cu	V	As	Hg	F
pH	1.000																		
Salinity	-0.972	1.000																	
Alkalinity	-0.881	0.954	1.000																
Turbidity	-0.466	0.648	0.805	1.000															
SG	-0.645	0.785	0.924	0.959	1.000														
TDS	-0.997	0.983	0.893	0.501	0.666	1.000													
BOD	-0.884	0.951	0.988	0.812	0.919	0.893	1.000												
Nitrate	-0.450	0.600	0.811	0.891	0.933	0.468	0.778	1.000											
Phosphate	-0.575	0.708	0.884	0.929	0.983	0.586	0.875	0.969	1.000										
Sulphate	-0.426	0.581	0.761	0.924	0.930	0.442	0.750	0.875	0.931	1.000									
Pb	-0.830	0.906	0.983	0.838	0.949	0.835	0.988	0.847	0.930	0.813	1.000								
Cd	-0.432	0.604	0.789	0.986	0.962	0.455	0.798	0.923	0.960	0.952	0.846	1.000							
Cr	-0.771	0.826	0.930	0.780	0.909	0.762	0.944	0.848	0.926	0.780	0.977	0.820	1.000						
Zn	-0.596	0.693	0.867	0.830	0.925	0.595	0.863	0.953	0.969	0.824	0.923	0.881	0.959	1.000					
Cu	-0.812	0.887	0.980	0.815	0.941	0.817	0.969	0.881	0.936	0.793	0.990	0.828	0.975	0.946	1.000				
V	-0.346	0.528	0.724	0.970	0.930	0.372	0.725	0.892	0.928	0.977	0.782	0.987	0.748	0.821	0.761	1.000			
As	-0.280	0.483	0.661	0.977	0.881	0.319	0.675	0.827	0.853	0.896	0.707	0.963	0.649	0.730	0.676	0.967	1.000		
Hg	-0.273	0.468	0.649	0.962	0.878	0.306	0.660	0.810	0.855	0.941	0.703	0.961	0.650	0.719	0.666	0.984	0.987	1.000	
F	-0.311	0.496	0.688	0.959	0.906	0.338	0.690	0.856	0.898	0.976	0.746	0.973	0.706	0.776	0.718	0.997	0.966	0.991	1.000

Table 5: Correlation coefficients of soil quality parameters within the cemetery environment

	Soil pH	Sal	Alk	Nit	Ph	Sul	Pb	Cd	Cr	Zn	Cu	V	As	Hg	F
Soil pH	1.000														
Salinity	0.252	1.000													
Alkalinity	0.803	0.301	1.000												
Nitrate	-0.031	-0.383	-0.225	1.000											
Phosphate	0.811	0.250	0.528	-0.171	1.000										
Sulphate	0.802	-0.061	0.464	0.269	0.718	1.000									
Pb	-0.690	-0.437	-0.774	0.513	-0.645	-0.373	1.000								
Cd	-0.280	0.396	-0.311	-0.313	-0.249	-0.460	-0.131	1.000							
Cr	-0.337	0.566	0.012	-0.563	-0.196	-0.683	-0.277	0.417	1.000						
Zn	-0.741	-0.434	-0.622	0.616	-0.695	-0.419	0.826	-0.235	-0.039	1.000					
Cu	0.145	-0.051	0.207	-0.557	0.388	0.233	-0.230	-0.242	-0.149	-0.391	1.000				
V	0.364	0.571	0.336	-0.215	0.157	0.333	-0.266	0.217	-0.148	-0.462	0.330	1.000			
As	-0.722	0.109	-0.367	-0.144	-0.761	-0.765	0.385	0.110	0.649	0.567	-0.331	-0.241	1.000		
Hg	0.495	0.565	0.585	-0.428	0.491	0.112	-0.646	-0.113	0.518	-0.487	0.000	0.082	0.076	1.000	
F	0.271	0.376	0.181	0.272	0.270	0.193	-0.094	-0.267	0.167	0.058	-0.434	-0.194	0.046	0.280	1.000

Table 6: Correlation coefficient of soil quality parameters at measured distances from the cemetery

	Soil pH	Sal	Alk	Ni	Phos	Sulp	Pb	Cd	Cr	Zn	Cu	V	As	Hg	F
Soil pH	1.000														
Salinity	-0.512	1.000													
Alkalinity	-0.327	0.610	1.000												
Nitrate	-0.502	0.701	0.567	1.000											
Phosphate	-0.515	0.816	0.324	0.699	1.000										
Sulphate	-0.301	0.755	0.580	0.909	0.641	1.000									
Pb	-0.642	0.884	0.751	0.880	0.805	0.832	1.000								
Cd	-0.680	0.625	0.600	0.910	0.724	0.748	0.902	1.000							
Cr	-0.593	0.569	0.519	0.802	0.719	0.701	0.814	0.921	1.000						
Zn	-0.634	0.728	0.721	0.933	0.592	0.815	0.915	0.900	0.757	1.000					
Cu	-0.479	0.891	0.769	0.897	0.764	0.896	0.975	0.842	0.734	0.905	1.000				
V	-0.330	0.686	0.499	0.793	0.761	0.735	0.770	0.749	0.667	0.662	0.795	1.000			
As	-0.314	0.822	0.477	0.788	0.666	0.882	0.752	0.608	0.636	0.694	0.801	0.774	1.000		
Hg	-0.282	0.803	0.412	0.475	0.718	0.543	0.628	0.423	0.548	0.427	0.625	0.683	0.824	1.000	
F	-0.444	0.613	0.422	0.931	0.611	0.808	0.746	0.808	0.730	0.839	0.764	0.822	0.828	0.557	1.000

3.2. Statistical Analysis

Table 4 displays the correlation findings for borehole water quality measurements, whereas Tables 5 and 6 display the correlation results for soil quality metrics inside the cemetery and measured distances from the cemetery, respectively. There was a substantial positive association between V and F (0.997), Hg and F (0.991), Pb and Cu (0.990), BOD and Pb, Alk and BOD (0.988), As and Hg, Cd and V (0.987), Turb. and Cd (0.986), V. and Hg (0.984), Sal. and TDS, Alk and Pb, SG and Phosphate (0.983) for borehole water samples. This shows that their distribution was strongly related, i.e., r>0.5. pH and TDS (-0.997), pH and Sal. (-0.972), pH and BOD (-0.884), pH and Alk. (-0.881), and pH and Pb all had a substantial negative association coefficient (-0.830). Similarly, there was a high positive association in soil quality indicators between pH and Phosphate (0.811), pH and Alk. (0.803), and pH and Sul. (0.802) for soil samples collected in a cemetery. There was also a substantial negative correlation coefficient between Alk. and Pb (0.774), Sul. and As (-0.765), and Phosphate and As (-0.761). For soil samples collected at specified distances from the cemetery, there was a substantial positive correlation between Pb and Cu (0.975), Ni and F (0.931), Cd and Cr (0.921), Pb and Zn (0.915), and Ni and Cn (0.910), indicating that their distribution was highly connected, i.e., r>0.5. There was also a substantial negative correlation coefficient between pH and Cd (-0.680), pH and Pb (-0.642), pH and Zn (-0.634), and pH and Cr (-0.593). For borehole water samples, higher coefficients of variation were observed in As (160.409 percent), F (144.341 percent), V (135.010 percent), Ni (98.230 percent), and Hg (83.666 percent), whereas TDS (5.379 percent), SG (5.390 percent), pH (12.218 percent), Sul. (13.073 percent), and Turb. (24.711 percent) had lower and narrow coefficients. Apparently, higher coefficients of variation were observed in Hg (249.929 percent), As (157.639 percent), F (84.234 percent), Pb (78.263 percent), and Cd (72.110 percent) for soil samples obtained at measured distances from the cemetery, whereas soil pH (2.346 percent), Sal. (20.639 percent), and Alk. (31.526 percent) had lower coefficients. CV values of elements dominated by natural sources are relatively low, according to Han et al. (2006), but CV values of elements affected by non-natural sources (biological and anthropogenic) are often high.

Table 7: Coefficient of variation for water quality parameters

Variable	MEAN	SE MEAN	S.D	VARIANCE	C.V	MIN	MAX.
pH	5.370	0.443	0.656	0.430	12.218	4.980	6.700
Salinity	7.813	2.441	3.666	13.437	46.916	0.490	10.700
Alkalinity	7.980	1.423	2.034	4.139	25.494	4.300	10.120
Turbidity	1.177	0.216	0.291	0.085	24.711	0.890	1.700
SG	1.003	0.042	0.054	0.003	5.390	0.931	1.083
TDS	6.895	0.252	0.371	0.138	5.379	6.140	7.080
BOD	2.850	0.627	0.872	0.761	30.606	1.290	3.830
Nitrate	0.698	0.606	0.685	0.470	98.230	0.056	1.607
Phosphate	0.474	0.313	0.377	0.142	79.529	0.033	0.984
Sulphate	1.148	0.127	0.150	0.023	13.073	1.013	1.358
Pb	0.922	0.393	0.527	0.277	57.147	0.040	1.505
Cd	0.440	0.208	0.268	0.072	60.952	0.201	0.893
Cr	0.571	0.299	0.367	0.135	64.312	0.016	0.917
Zn	2.094	1.290	1.513	2.290	72.257	0.319	3.760
Cu	1.326	0.592	0.757	0.573	57.103	0.081	2.098
V	0.157	0.173	0.211	0.045	135.010	0.001	0.507
As	0.050	0.059	0.080	0.006	160.409	0.001	0.203
Hg	0.002	0.001	0.002	0.000	83.666	0.001	0.005
Formaldehyde	0.031	0.037	0.045	0.002	144.341	0.001	0.106

Table 8: Coefficient of variation for soil quality parameters within the cemetery

Variable	MEAN	SE MEAN	S.D	VARIANCE	C.V	MIN	MAX.
Soil pH	5.650	0.576	0.687	0.471	12.152	4.910	6.890
Salinity	17.510	2.828	3.441	11.843	19.654	12.100	22.300
Alkalinity	16.664	2.911	3.562	12.684	21.372	12.610	22.900
Nitrate	12.580	1.912	2.371	5.623	18.850	9.370	16.580
Phosphate	8.132	2.216	2.573	6.621	31.641	5.160	12.610

Sulphate	9.810	2.540	2.965	8.794	30.229	4.860	13.090
Pb	0.993	0.155	0.197	0.039	19.855	0.601	1.224
Cd	0.978	0.093	0.122	0.015	12.515	0.811	1.218
Cr	1.075	0.248	0.277	0.077	25.785	0.730	1.465
Zn	4.647	0.771	0.967	0.935	20.811	3.325	6.157
Cu	2.324	0.406	0.614	0.377	26.427	1.789	3.925
V	1.166	0.096	0.118	0.014	10.125	1.041	1.401
As	1.194	0.277	0.351	0.123	29.388	0.701	1.802
Hg	0.499	0.111	0.162	0.026	32.457	0.201	0.803
Formaldehyde	4.280	1.113	1.301	1.692	30.393	2.498	6.103

Table 9: Coefficient of variation for soil quality parameters at measured distances from the cemetery

Variable	MEAN	SE MEAN	S.D	VARIANCE	C.V	MIN	MAX.
Soil pH	5.236	0.093	0.123	0.015	2.346	5.020	5.440
Salinity	8.590	1.308	1.773	3.143	20.639	7.100	12.400
Alkalinity	4.553	1.116	1.435	2.060	31.526	2.620	7.340
Nitrate	3.053	1.125	1.392	1.939	45.609	0.860	5.020
Phosphate	0.973	0.326	0.436	0.190	44.765	0.340	1.820
Sulphate	3.197	1.392	1.735	3.011	54.278	1.010	6.300
Pb	0.148	0.093	0.116	0.013	78.263	0.001	0.332
Cd	0.340	0.204	0.245	0.060	72.110	0.001	0.618
Cr	0.273	0.124	0.154	0.024	56.378	0.010	0.489
Zn	2.281	1.395	1.595	2.543	69.921	0.325	4.820
Cu	1.399	0.733	0.878	0.771	62.780	0.082	2.818
V	0.139	0.075	0.097	0.009	70.158	0.001	0.328
As	0.174	0.202	0.274	0.075	157.639	0.001	0.811
Hg	0.027	0.039	0.068	0.005	249.929	0.001	0.221
Formaldehyde	0.370	0.270	0.312	0.097	84.234	0.002	0.856

Table 10: Analysis of vaiance for water quality parameters and distance

Source of Variation	SS	df	MS	F	P-value	F crit
Parameters	796.291094	18	44.2383941	47.359145	5.08036E-38	1.71959245
Distance	31.0656906	5	6.21313812	6.65143739	2.58643E-05	2.31568924
Error	84.0694121	90	0.93410458			
Total	911.426197	113				

Table 11: Analysis of vaiance for soil quality parameters and distance

Source of Variation	SS	df	MS	F	P-value	F crit
Parameters	869.329208	14	62.0949434	104.636329	3.06856E-62	1.77102353
Distance	50.8256899	9	5.64729888	9.51627609	5.69386E-11	1.95495261
Error	74.7729104	126	0.5934358			
Total	994.927809	149				

Table 12: Analysis of vaiance for soil quality parameters and depth

Source of Variation	SS	df	MS	F	P-value	F crit
Parameters	4778.4532	14	341.31808	109.7922	1.916E-63	1.7710235
Depth	52.310993	9	5.8123325	1.8696601	0.0623219	1.9549526
Error	391.70431	126	3.1087643			
Total	5222.4685	149				

The data were subjected to analysis of variance to ensure that the variation in the water and soil quality metrics obtained from various locations and depths is significant and not due to chance (ANOVA). The computed F-value for water samples at the 0.05 level of significance for water quality metrics is 47.359, which is substantially more than the critical F value of 1.719 indicated in Table 10. This demonstrates that there is a substantial variation in the water quality metrics. The computed F-value for variation in water quality parameters owing to distance from the cemetery, on the other hand, is 6.651, which is greater than the critical F-value of 2.316. This demonstrates that water quality metrics are affected by distance from the cemetery. However, for soil quality parameters and distance, the computed F-value at 0.05 significance level is 104.636, which is significantly greater than the critical F value of 1.771, as shown in Table 11. This confirms that there is a large difference in the soil quality parameters. Similarly, the computed F-value for change in soil quality metrics caused by distance from the cemetery is 9.516, which is much more than the critical F-value of 1.955. This also shows that soil quality measures are affected by distance from the cemetery. Table 12 also displays the results of the analysis of variance for soil quality metrics and depth. The computed F-value for soil quality parameters at the 0.05 significance level is 109.792, which is significantly greater than the critical F value of 1.771. This demonstrates that there is a large difference in the soil quality metrics. The computed F-value for change in soil quality parameters owing to depth within the cemetery is 1.8696, which is lower than the crucial F-value of 1.9549. This means that the soil quality metrics of soil samples collected within the cemetery are not affected by depth.

4. DISCUSSION

Despite the degradation of its quality in some areas due to various anthropogenic activities, groundwater has been used as a source of drinking water for many decades and continues to be useful for this purpose to this day (Radajevic, and Bashkin, 1999). As a result, monitoring groundwater quality is an unavoidable practice for guaranteeing environmental sustainability. The physical and chemical characteristics reported in this study are among those typically recommended as monitoring criteria and as the first approach for detecting groundwater impacts from cemeteries (Tredoux et al., 2004). Except for the reference sample, the samples obtained within a 500-metre radius of the cemetery indicate that the groundwater in the area is slightly acidic (with pH ranging between 4.98-5.22). Water quality parameters such as salinity, total dissolved solids, BOD, and heavy metals were found to be higher in all water samples collected at the same radius. TDS and cadmium, however, had percentage concentrations greater than the permitted limit in portable water of all the water parameters tested in the reference sample. The following parameters are commonly influenced by decomposition processes in cemeteries: pH, EC, Cl, NO3, SO4, P, Na, K, Ca, and Fe (Idehen and Ezenwa, 2019; Tredoux et al., 2004; Sawyer et al., 2003; Young et al., 2002). Other parameters, with the exception of nitrate, phosphate, sulphate, and turbidity, were typically higher in groundwater samples taken from the cemetery's perimeter when compared to the international permitted limit in drinking water. Furthermore, Tredoux et al. (2004) proposed including Mn, Cd, Cr, Cu, Ni, Pb, and Zn at high risk areas; these heavy metals, particularly Pb, Cd, Cu, and Zn, were the most influential parameters pertaining to the cemetery. The lead levels were less than the WHO (2011) recommended threshold of 0.01 mg/l. The most prevalent environmental pollutant discovered in soils is lead. Lead, unlike other metals, has no biological function and is possibly hazardous to microbes (Sobolev & Begonia, 2008). Its overabundance in biological organisms is always harmful. Furthermore, lead exposure in humans can result in seizures, mental impairment, and behavioural abnormalities (Adelekan and Abegunde, 2011). The buildup of heavy metals in the human body may cause organ dysfunction (Jarup, 2003). Cr and Cd have been discovered as carcinogenic agents, whereas Pb has been identified as a neutrotoxic and enzyme inhibitor (Ernest, 2010). Because of its toxicity, nitrate concentrations are of concern. Nitrate concentrations in drinking water more than 10mg have been linked to methaemoglobinemia in neonates, a disease characterised by cyanosis, a bluish colouration of the skin, and the so-called "blue-baby" syndrome. Infants under three months of age are most vulnerable to this sickness (Radojevic & Bashkin, 1999). These alterations, together with the other variations

noted above, can be interpreted as unambiguous signs of the influence of the cemetery's decomposition activities on the quality of the water in the aquifer under the cemetery. Furthermore, the significant levels of physicochemical and heavy metal contamination identified in the most of the sampled locations indicate that the cemetery might be a potential source of groundwater contamination. The cemetery soil contamination was evaluated using a ratio of on-to-off-site mineral content, and it was discovered that present burial practices had a significant influence, as the mineral contents of off-site soil samples were much higher than those of on-site samples.

5. CONCLUSION AND RECOMMENDATION

Agricultural waste, industries, and landfills are often regarded as the primary anthropogenic causes of environmental contamination; nevertheless, cemeteries have received little attention as potential sources of pollution and groundwater contamination. Cemeteries in Nigeria have not been viewed as having substantial potential pollutant effects on the environment, although they are frequently placed near communities that rely on groundwater sources for water supply. If burial precautions are not taken appropriately, they may have an impact on the groundwater quality parameters of boreholes positioned at varied radial distances from the cemetery. Using both soil and water quality parameters as indices of a cemetery's environmental impact, there is considerable evidence of environmental contamination resulting from cemetery operations in the study area owing to site overload. Legislation, a review of sitting methodology, and management issues such as longevity of remains, grave re-use, funeral artifacts and buffer zone, as well as planning policies, will go a long way toward reducing the soil and water resource risk and environmental hazards associated with cemetery operation. The increased grave density at the cemetery will pose a severe danger to groundwater quality over time. Proper cemetery management procedures should be followed to guide the suitable location of cemeteries, which will improve interment and maintain environmental pollution controls. Some infections are now being linked to human corpses, and there is significant worry about their detrimental consequences, although no records have been identified that unambiguously link large outbreaks to burial places. To dispel uncertainties, detailed and explicit investigations should be conducted.

Conflict of Interest

The author declares that there are no conflicts of interests.

Data and materials availability

All data associated with this study are present in the paper.

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